EFFECT OF HARVESTING METHOD ON FIBER AND YARN QUALITY FROM IRRIGATED COTTON ON THE HIGH PLAINS

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Abstract

In recent years, Texas cotton production has represented almost half of all the US cotton production, with most of that production coming from the High Plains. Due to the harsh weather conditions, most cotton on the High Plains is of more storm-proof varieties that are harvested using stripper harvesters. Unlike picker harvesters, which use spindles to remove seed cotton from the boll, stripper harvesters use brushes and bats that indiscriminately remove seed cotton, bolls, leaves, and branches from the plant. As a result, stripper harvested cotton contains more foreign matter than picked cotton and generally contains more immature fibers that are left on the plant by spindle harvesters.

Stripper harvesters have several advantages over picker harvesters, including lower purchase prices, fewer moving parts leading to lower fuel and maintenance requirements, and greater efficiency in low yielding cotton. Picker harvesters, however, pick cleaner cotton, are perceived to maintain fiber quality better than strippers, and are able to harvest at higher speeds in high yielding stands.

Foreign textile mills continue to raise their standards for fiber quality as cotton spinners are forced to compete with synthetic fibers. Increased yields in the region and higher quality demands have the potential to make harvesting High Plains cotton with pickers an attractive option.

The objective of this research is to compare fiber and yarn quality from four varieties of cotton harvested on the High Plains using modern picker and stripper harvesters.

Introduction

Over a fourth of the cotton bales produced in the United States since 2002 have been produced in Texas with most of that cotton coming from the High Plains region, and in recent years, Texas cotton production has represented almost half of all the US cotton production (USDA-NASS, 2008). Five of the eight distinct cotton producing regions in Texas, including the High Plains, Rolling Plains, Central Blackland, Coastal Bend, and Winter Garden regions, are primarily harvested using stripper harvesters, while the Upper Gulf Coast, Rio Grande Valley, and El Paso/Trans-Pecos regions primarily use picker harvesters (Nelson et al., 2001). Approximately 85 percent of the cotton produced in Texas is currently stripper harvested (Glade et al., 1996).

Unlike picker harvesters, which use spindles to remove seed cotton from the boll of the plant, stripper harvesters use brushes and bats that indiscriminately remove seed cotton, bolls, leaves, and many branches from the stem of the plant. As a result, stripper harvested cotton contains more foreign matter than spindle picked cotton. This increased foreign matter leads to higher transportation costs per bale to haul modules to the gin as well as potentially higher costs of processing the cotton, due to the use of additional cleaning machinery at the gin. Foreign matter may be reduced by the use of a field cleaner (often called a burr extractor), but foreign matter levels are still greater than found in spindle picked cotton.

Stripper harvesters do have several advantages over picker harvesters, including lower purchase prices, fewer moving parts in the row units, lower fuel consumption and maintenance requirements, and faster ground speeds in low yielding cotton. Picker harvesters, however, pick cleaner cotton, are perceived to maintain fiber quality characteristics better than strippers, and are able to harvest cotton at higher speeds in high yielding stands.

As irrigation technology has improved and new cotton varieties have been introduced and adopted on the High Plains, yields in the region have dramatically increased, sometimes reaching four to five bales per acre. It is estimated that between 300,000 and 400,000 acres of drip irrigation has been installed on the High Plains in the past ten years for cotton production, and over 1.1 million acres are irrigated with center pivot systems equipped with high efficiency application packages. Furthermore, foreign textile mills continue to raise their standards for fiber quality as cotton spinners are forced to compete with synthetic fibers that are not plagued with fiber contamination and degradation. These increased yields and higher quality demands have the potential to make harvesting High Plains cotton with pickers an attractive option.

While research has been conducted to compare fiber quality between stripper and picker harvested cotton, most of this research focused on lower yielding stands of cotton and used harvest machinery that was not representative of modern harvest systems. Furthermore, fiber quality traits are not always sufficient to indicate spinning performance and yarn quality, especially if the only fiber quality traits analyzed are those indicated by the current USDA cotton classing system.

Comparing fiber quality between picker and stripper harvested cottons, Brashears and Hake (1995) found better leaf grades in Paymaster HS26 harvested with a picker harvester versus a stripper harvester with and without field cleaning, but there was no difference in leaf grade between the harvest treatments for Stoneville 132. No significant effects were seen in High Volume Instrument (HVI) staple length, micronaire, strength, length, or length uniformity between harvest methods. The two-row picker used by Brashears and Hake (1995) does not reflect the advances in technology of modern harvest machinery, making application of this study to modern production systems questionable.

Vories and Bonner (1995) compared fiber quality between stripped (with field cleaning) and picked dryland cotton in Arkansas. None of the HVI parameters were significantly different between harvest methods. In 1992, when weather conditions were more harsh, fiber quality indices were better for picker harvested cotton than for stripper harvested cotton, confirming the finding of Kerby et al. (1986) that grade differences between harvest methods are most pronounced during years of adverse conditions. Though not significantly different, micronaire values for stripped cotton were lower than those of picked cotton for two of the three years of the study. Again, the brush stripper used in the Vories and Bonner (1995) study (an Allis Chalmers 880 with alternating brushes and flaps) does not represent modern harvesting machinery, making extrapolation of these results to modern production systems tenuous.

Baker and Brashears (2000) evaluated the effect of field cleaners on fiber and yarn quality of three stripper varieties of cotton. They found that lint trash content was significantly reduced at each stage of lint cleaning by using field cleaners, thus resulting in somewhat better color and leaf grades. Half of the samples analyzed indicated a one leaf grade improvement from use of a field cleaner. Field cleaned cotton also had some higher micronaire and maturity ratios and reduced nep counts in fiber and yarn. For open-end spun yarn, the field cleaned cotton produced yarn with slightly higher evenness coefficient of variation (CV) and more thin places. All other measured yarn factors were unaffected by the use of a field cleaner.

Brashears and Baker (2000) compared the quality of two varieties of cotton harvested using a finger stripper, a brush roll stripper (both with field cleaners), and a spindle picker. Leaf grades were similar for Paymaster 2200 regardless of harvest method, while the leaf grade for picker harvested D&PM 1220 was significantly lower for the same variety harvested with both strippers. For both varieties, the fiber length of picked cotton was longer and the micronaire was higher than that of the same variety that was stripped. Fiber length of brush stripped cotton was also significantly longer than finger stripped cotton. For both varieties, nep counts were significantly lower for the picker harvested cotton than for the stripped cotton.

Willcutt et al. (2002) compared lint quality as affected by harvester type for picker varieties grown on the Mississippi delta. They observed better values in nep counts, short fiber content by weight, visible foreign matter and immature fiber content for picked cotton than stripped cotton samples. Classer staple, HVI length, uniformity, and strength were not affected significantly by harvest method.

Faircloth et al. (2004) evaluated turnout, fiber quality, and loan value from cotton harvested using brush strippers versus spindle harvesters in northeast Louisiana. Yields in this study ranged from 1.23 to 2.70 bales per acre (assuming 480 pound bales). Few statistically significant differences in fiber quality from the two harvesting treatments were observed, but trends of decreased micronaire and increased color grade in stripper harvested cotton were seen. Incorporating differences in yield, fiber quality, and input costs, Faircloth et al. (2004) determined that stripper harvesting increased overall revenue during one of the two years of the study. However, whereas stripper harvested cotton traditionally requires more seed cotton cleaning and/or lint cleaning at the gin than spindle picked cotton leading to greater fiber breakage, additional cleaning, and higher ginning costs, ginning treatments were not varied between stripper and picker harvested samples (J.C. Faircloth, personal communication, 04 October 2006). This lack of additional cleaning led to an incomplete analysis of typical system inputs. Furthermore, the varieties and yields used in the study are not representative of those used on the High Plains and make extrapolation to this region troublesome.

McAlister and Rogers (2005) investigated the effect of harvesting method on fiber and yarn quality from Ultra-Narrow-Row cotton grown in South Carolina. Due to varietal differences, the use of Ultra-Narrow-Row cotton, and the extreme weathering of the cotton before harvest, the applicability of the results of this study to the High Plains is questionable. However, the protocols for fiber and yarn testing employed in the McAlister and Rogers study are helpful in determining the effect of harvesting method throughout the processing chain.

The objective of this research is to comprehensively compare picker and stripper cotton harvesters in irrigated cotton on the High Plains of Texas. Specifically, this paper focuses on differences in fiber and yarn quality from cotton harvested on the High Plains of Texas using a picker harvester, a stripper harvester with a field cleaner, and a stripper harvester without a field cleaner. Each of these components will later be incorporated into a larger cost-benefit analysis to determine the feasibility of replacing stripper harvesters with picker harvesters on the High Plains of Texas.

Materials and Methods

Sample collection

In 2006, irrigated cotton (Stoneville 4554 B2RF) was produced on 76.2-cm (30-inch) rows at a commercial farm approximately 24 km west of Plains, Texas. Production practices throughout the growing season were typical for the High Plains region. Cotton was harvested in late October/early November 2006 using a six-row John Deere 9996 spindle picker with Pro-16 row units equipped with scrapping plates, a six-row John Deere 7460 stripper harvester with field cleaner, and the same stripper harvester bypassing the field cleaner. Defoliation and harvest aid treatments were identical for both picked and stripped cotton based on the producer's observations of harvest readiness. Prior to harvest, the harvesting method used in each pass of the field was completely randomized with four replications per harvest treatment. Both the picker and stripper harvesters used were six-row models, so each pass consisted of a block of twelve rows.

In 2007, four varieties of cotton (FiberMax 9058 F; FM 9063 B2RF; PhytoGen 485 WRF; and Stoneville 4554 B2RF) were produced on two farms on the High Plains. At the first farm, near Muleshoe, Texas, cotton was grown on 76.2-cm (30-inch) rows while at the second farm, east of Plains, Texas, cotton was grown on 102-cm (40-inch) rows. Again, production practices throughout the growing season were typical for the High Plains region. Cotton was harvested in October and November 2007 using a six-row John Deere 9996 spindle picker with Pro-16 row units equipped with scrapping plates on the rear drums, and a six-row John Deere 7460 stripper harvester with a field cleaner. Defoliation and harvest aid treatments were identical for both picked and stripped cotton based on the producer's observations of harvest readiness. A split-plot statistical design was used such that, for each replication, six rows were picked and an adjacent six rows were stripped. At both farms, three replications of each harvester by variety treatment were sampled.

During both years, a 140-kg sample of seed cotton was collected from each sample plot, thus maintaining true replicated samples. Samples were placed in bulk seed bags and stored for ginning. Samples were ginned at the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, Texas, on a commercial-size gin. Due to late season rains in 2006, the leaf trash was difficult to separate from the seed cotton, so cotton from all harvesting treatments was subjected to the same cleaning regime, including two stages of seed cotton cleaning (using a tower dryer, incline cleaner, and a stick machine) and two stages of saw-type lint cleaning. In 2007, only one stage of lint cleaning was used. After ginning, samples were taken to the International Textile Center for fiber and yarn quality analyses.

Fiber and yarn quality tests

Lint samples were conditioned at 65% RH ± 2% and 21^{o}C ± 1 (according to ASTM D1776-04 Standard Practice for Conditioning of Textiles) for fiber quality analysis and tested using an HVI (Model 900A, USTER®) with 4 micronaire readings, 4 color readings, and 10 length and strength readings per sample and the AFIS with 5 replications of 3,000 fibers tested per sample. Carded yarn tests and carded-and-combed yarn tests were then conducted. Carded and combed samples were spun on a Suessen Elite ring spinning frame with a 40Ne yarn count and a twist of 4.2 (weaving twist). Yarn count and skein break tests were conducted using a Scott Tester (ten bobbins tested per sample); yarn force to break, elongation, tenacity, and work to break were tested using a Uster Tensorapid 3 (ten bobbins tested per sample and ten breaks per bobbin); and yarn evenness was tested using an Uster Tester 3 (ten bobbins tested per sample and 400 meters per bobbin).

All treatment means were compared using the General Linear Model function in SPSS (SPSS, Inc., Chicago, IL). A multivariate analysis of variance (MANOVA) was conducted to determine overall differences between harvest treatments before conducting pair-wise comparisons. The null hypothesis tested in all cases was that means in each harvest treatment were equal. Means were compared using the Least Significant Difference (LSD) pair-wise multiple comparison test. Kolmogorov-Smirnov tests were used to compare fiber length distributions between harvest treatments. A 0.05 level of significance was used in all tests except where noted differently.

Results and Discussion

Because samples collected in 2007 were substantially more mature than samples collected in 2006, the results from each year are presented separately.

Fiber quality

2006

The results from HVI and selected parameters from AFIS testing from samples collected in 2006 are shown in tables 1 and 2, respectively. Caution should be used when interpreting results because fiber maturity for all samples was low, which may exacerbate differences in fiber quality parameters as a function of harvest treatment because the thin secondary wall of the fibers may lead to lower fiber strength and elongation. Results of MANOVA analyses (n = 4 for each treatment) indicated that overall treatment differences were not detected for HVI results at 95% confidence level, so the results of pair-wise comparisons of HVI data should be analyzed cautiously. Treatment differences were detected by MANOVA when analyzing results of AFIS tests ($p<0.0005$ using Wilk's Lambda).

Table 1. Results from 2006 HVI analysis.[a]

	Picked	Stripped with FC	Stripped w/o FC
Micronaire	3.5x	3.2y	3.2y
Length (in.)	1.11x	1.09y	1.10x,y
Uniformity (%)	80.4x	79.4y	79.2y
Strength (g/tex)	27.1x	26.2x	26.6x
Elongation (%)	8.4x	8.7x	8.5x
Reflectance (%)	81.6x	81.1x,y	80.9y
Yellowness	8.1x	8.5x,y	8.7y
Leaf	2.0x	2.5x	2.3x

[a] No significant differences were detected ($\alpha = 0.05$) between means in the same row followed by the same letter.

Table 2. Selected results from 2006 AFIS analysis.[a]

	Picked	Stripped with FC	Stripped w/o FC
Nep count (neps/g)	561x	661x,y	702y
Short fiber by weight (%)	16.1x	17.3x	17.7x
Visible foreign matter (%)	1.06x	1.18x	1.15x
Immature fiber content (%)	12.8x	13.7x	13.8x
Maturity ratio	0.78x	0.78x	0.77x

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.

Micronaire for spindle picked cotton was significantly higher than for either stripper treatment, confirming the results of Brashears and Baker (2000). Stripper harvesters tend to have higher harvesting efficiencies than pickers; however, the increase in lint fiber harvested is typically comprised of less mature fibers that therefore have lower micronaire values. Length uniformity was also significantly better for picked cotton versus both stripper treatments. Both micronaire and length uniformity values for picked cotton were within the base market value range, while both stripper treatments led to micronaire and length uniformities in the discount range. Unlike the results from Baker and Brashears (2000) no differences were seen in fiber quality parameters between stripped cotton that was field cleaned versus non-field cleaned cotton.

Average AFIS length distributions by number for all treatments are shown in fig. 1. All length distributions are poor and skewed to the right due to the lack of maturity. Nevertheless, we can see that the fiber length distribution of the picked cotton is slightly better (less fiber fragments, less short fibers, and more of the longer fibers). Results of the Kolmogorov-Smirnov tests showed significant differences between the fiber length distributions of the picked samples and both stripped samples ($p < 0.01$), but no significant difference was detected between the fiber length distributions of the stripped samples with and without a field cleaner.

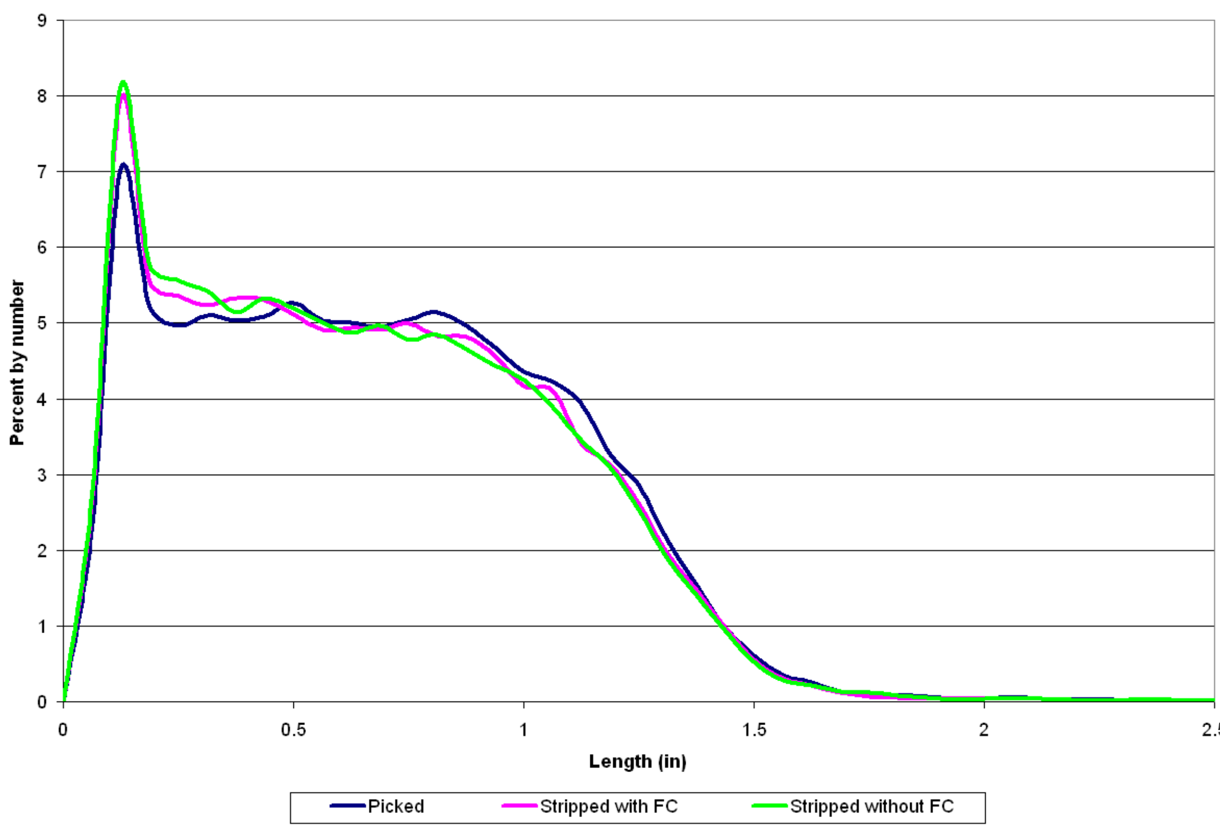

Figure 1. 2006 AFIS length distributions by number.

No significant interactions were detected between harvest treatment and lint cleaning for fiber quality parameters testing with HVI and AFIS. As expected, lint cleaning resulting in a greater reduction in visible foreign matter for both stripper treatments than for picked cotton. However, no differences were detected in the change in length, strength, nep count, nor nep size of fibers between harvest treatments suggesting that differences in fiber quality reported in tables 1 and 2 are the result of harvest treatment rather than interactions between harvest treatment and lint cleaning.

2007

The average results of HVI and selected parameters of AFIS testing from samples collected in 2007 are shown in tables 3 and 5, respectively. A MANOVA test using Wilk's Lambda revealed significant differences in HVI and AFIS results as a function of harvest location, variety, and treatment (all p-values < 0.0005; $n = 24$ for each treatment). Multivariate interactions were also significant between variety and location ($p < 0.0005$ for HVI; $p = 0.008$ for AFIS) as well as variety and harvest treatment ($p = 0.036$ for HVI; $p = 0.043$ for AFIS).

Table 3. ANOVA results from 2007 HVI analysis.[a]

	Picked	Stripped with FC	Significant Variables[b]
Micronaire	4.2x	4.0x	None
Length (in.)	1.17x	1.16x	V, L, V*L
Uniformity (%)	82.1x	81.9x	V, L, V*L
Strength (g/tex)	29.3x	29.6x	V, L, V*L
Elongation (%)	8.7x	8.7x	V, L
Reflectance (%)	80.9x	79.9y	V, L, T, V*T
Yellowness	8.3x	8.6y	V, L, T
Leaf	1.3x	1.8y	V, T

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.
[b] V = variety; L = location; T = harvest treatment; V*L = variety-location interaction; V*T = variety-treatment interaction

While differences in treatment means were detected only in color and leaf grades, a paired-samples t-test (α = 0.05) was conducted comparing differences in HVI parameter values between picked and stripped samples from the same plot to reduce varietal and location impacts. Results of the paired-samples t-test revealed significant improvements in micronaire, reflectance, yellowness, and leaf grade from picked samples versus stripped samples (table 4).

Table 4. Selected paired sample t-test results from 2007 HVI analysis.

	Mean Difference[a]	p-value
Micronaire	0.1	0.001
Reflectance (%)	1.0	<0.0005
Yellowness	-0.3	<0.0005
Leaf	-0.5	0.005

[a] Mean difference = (Avg. of picked samples) – (Avg. of stripped samples).

Table 5. Selected ANOVA results from 2007 AFIS analysis.[a]

	Picked	Stripped with FC	Significant Variables[b]
Nep count (neps/g)	310x	370y	V, L, T
Short fiber by weight (%)	10.3x	10.8y	V, L, T, V*L, V*T
Visible foreign matter (%)	1.46x	2.23y	V, T, V*T
Immature fiber content (%)	8.7x	9.5y	V, L, T, V*L
Maturity ratio	0.85x	0.84y	V, T

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.
[b] V = variety; L = location; T = harvest treatment; V*L = variety-location interaction; V*T = variety-treatment interaction

Differences in micronaire values between harvest treatments were less pronounced in 2007 than 2006, but on average, fibers were more mature in 2007 due to better growing conditions, as can be seen by the more normal shape of the AFIS length distribution for FM 9058 from 2007 (fig. 2) compared to 2006 (fig. 1). These results confirm the conclusions of Kerby et al. (1986) that grade differences between harvest methods are more pronounced during years of adverse growing conditions. As with the results from Willcutt et al., (2002), significant differences were detected between harvest treatments in nep counts, short fiber content, and visible foreign matter in 2007, but nep counts and short fiber content were both reduced relative to 2006 values. Significant differences ($p < 0.01$ for all tests) were detected between the average fiber length distributions from each treatment for all varieties (see fig. 2 for example fiber length distributions from 2007). Overall, variety had a greater impact on fiber quality parameters than harvest treatment.

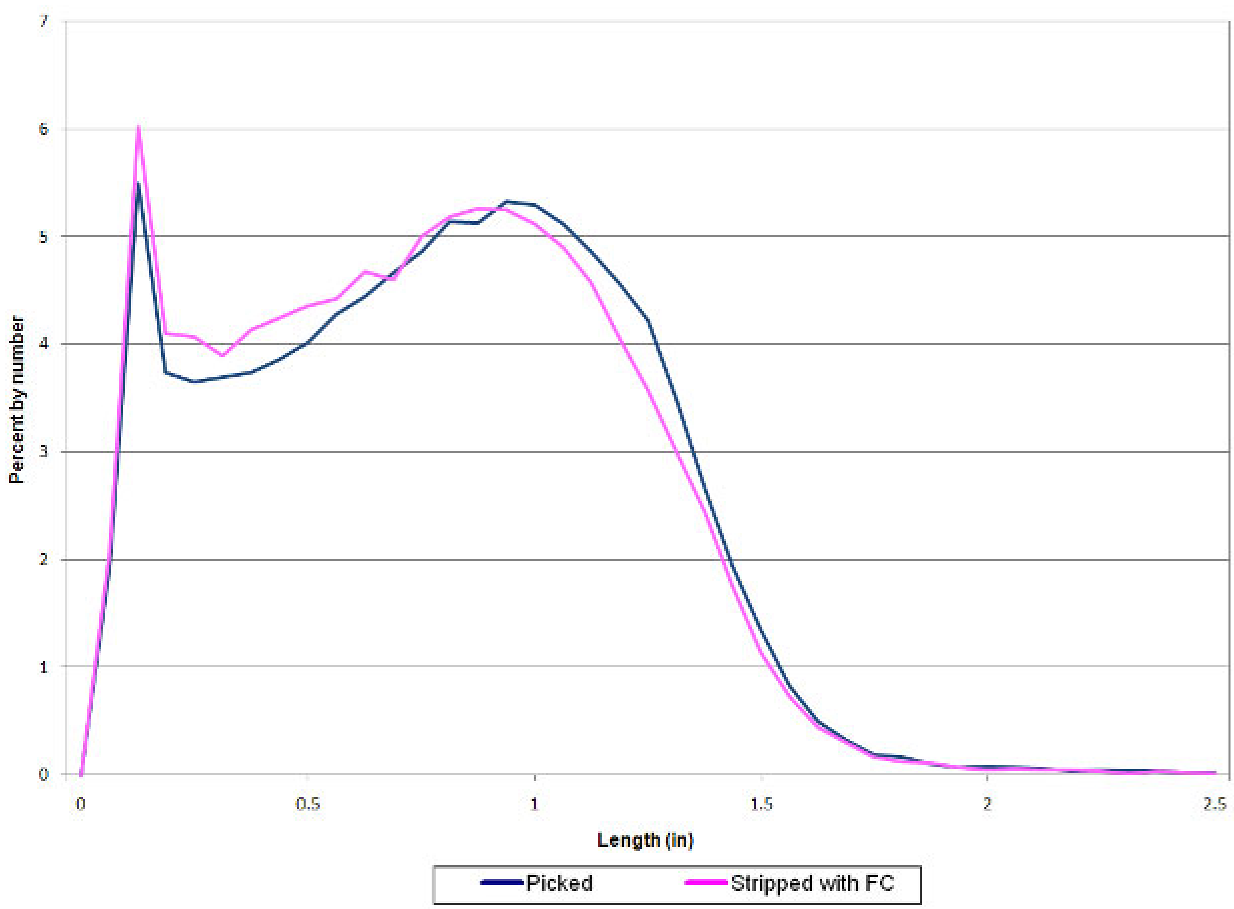

Figure 2. 2007 AFIS length distribution of FM 9058 F by number.

Differences in the quality of fibers as measured by the HVI led to significant differences in the value of lint by harvest treatment in 2006 but not in 2007 as indicated by the average loan values and West Texas spot prices (table 6; USDA-AMS, 2007).

Table 6. Average loan values and West Texas spot prices (USDA-AMS, 2007).[a]

	2006		2007	
	Loan ($/lbs)	**Spot Price ($/lbs)**	**Loan ($/lbs)**	**Spot Price ($/lbs)**
Picked	0.5738x	0.5268x	0.5907x	0.5408x
Stripped w/FC	0.5300y	0.5014y	0.5849x	0.5390x
Stripped w/o FC	0.5291y	0.4934y	--	--

[a] No significant differences were detected (α = 0.05) between means in the same column followed by the same letter.

No significant differences were detected the loan rates or spot prices between locations or varieties in 2007. The higher quality of picked cotton compared to stripped cotton from the same field led to higher average sale prices for picked cotton. The reduction in price for stripped cotton compared to picked cotton in both 2006 and 2007 was less severe than the reduction in loan value.

Yarn quality

2006

Selected results of carded-and-combed yarn testing are shown in tables 7 and 8, respectively. Treatment differences were detected in carded yarn tests (p=0.024 using Wilk’s Lambda) but not carded-and-combed yarn tests (p=0.205 using Wilk's Lambda) with MANOVA (n = 4 for each treatment). Therefore, pair-wise comparison tests of carded yarn tests may be analyzed as presented while combed yarn tests should be analyzed with more caution as an insignificant MANOVA result indicates an increased likelihood of a Type I error in which the null hypothesis is rejected even though it is true.

Table 7. Selected results of 2006 carded yarn analysis.[a]

	Picked		Stripped with FC		Stripped w/o FC	
	Value	**Quality[b] (%)**	**Value**	**Quality[b] (%)**	**Value**	**Quality[b] (%)**
CSP (N.tex)	2872.9x	N/A	2852.8x	N/A	2809.1x	N/A
Elongation (%)	7.80x	<5	7.91x	<5	7.87x	<5
Tenacity (cN/tex)	11.89x	>95	11.86x	>95	11.94x	>95
Work to Break (cN.cm)	376.5 x	49	380.4 x	47	382.0x	46
CV (%)	22.67x	>95	23.43y	>95	23.32x,y	>95
Thin Places (cnt/km)	597x	>95	742x	>95	736x	>95
Thick Places (cnt/km)	1641x	>95	1837x	>95	1808x	>95
Neps +200% (cnt/km)	1542x	>95	1787x	>95	1785x	>95
Hairiness	4.75x	14	5.08y	27	5.16y	30

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.
[b] Quality percentile is based on global yarn quality statistics for ring-spun carded yarn bobbins for weaving (USTER Technologies, 2007).

Table 8. Selected results of 2006 carded-and-combed yarn analysis.[a]

	Picked		Stripped with FC		Stripped w/o FC	
	Value	**Quality[b] (%)**	**Value**	**Quality[b] (%)**	**Value**	**Quality[b] (%)**
Noils (%)	17.05x	N/A	17.65x	N/A	18.52y	N/A
CSP (N.tex)	3378.4x	N/A	3309.6x	N/A	3274.8x	N/A
Elongation (%)	7.98x	<5	8.00x	<5	8.01x	<5
Tenacity (cN/tex)	13.42x	>95	13.40x	>95	13.26x	>95
Work to Break (cN.cm)	436.3x	14	433.5x	17	428.8x	20
CV (%)	16.81x	91	17.24y	>95	17.37y	>95
Thin Places (cnt/km)	47x	>95	58y	>95	55x,y	>95
Thick Places (cnt/km)	290x	89	348y	92	360y	92
Neps +200% (cnt/km)	1030x	>95	1260y	>95	1320y	>95
Hairiness	4.22x	39	4.41y	50	4.49y	55

[a] No significant differences were detected ($\alpha = 0.05$) between means in the same row followed by the same letter.
[b] Quality percentile is based on global yarn quality statistics for ring-spun combed yarn bobbins for weaving (USTER Technologies, 2007).

Little difference was detected in carded yarn quality based on harvest treatment with the exception of hairiness. However, greater differences were detected in carded-and-combed yarn quality indices. In addition to the reduced percentage of noils seen in picked and field cleaned cotton, picked cotton had a smaller CV, fewer thick and thin places, fewer neps, and was less hairy than both stripped treatments. It should be noted, however, that combing is not typically performed on fibers with a staple shorter than 36, which was the case for all three harvest treatments. Unlike Baker and Brashears (2000), no differences were seen in yarn evenness between field cleaned and non-field cleaned cotton, but Baker and Brashears (2000) analyzed open-end spun yarn rather than ring-spun yarn.

Compared to global averages, the yarn quality indices reported above for all harvest treatments indicate relatively poor yarn quality with a few exceptions: elongation for both carded and carded-and-combed yarns was excellent; work-to-break was average for carded yarns but good for carded-and-combed yarns; and hairiness, which was near average for carded-and-combed yarns but good for carded yarns.

2007

Selected results of carded-and-combed yarn testing are shown in tables 9 and 10, respectively. A MANOVA test using Wilk's Lambda (n = 24 for each treatment) revealed significant differences in carded yarn test results as a function of harvest location ($p < 0.0005$), variety ($p < 0.0005$), and harvest treatment ($p = 0.026$). Multivariate interactions were also significant between variety and location ($p < 0.0005$).

For carded-and-combed yarn tests, significant differences were detected as a function of harvest location ($p < 0.0005$) and variety ($p < 0.0005$) but not harvest treatment ($p = 0.150$). Therefore, pair-wise comparisons of carded yarn tests (table 9) may be analyzed as presented while carded-and-combed yarn tests (table 10) should be analyzed with more caution given the increased likelihood of a Type I error. For carded-and-combed tests, multivariate interactions were also significant between variety and location ($p = 0.001$).

Table 9. Selected results of 2007 carded yarn analysis.[a]

	Picked		Stripped with FC		Significant Variables[c]
	Value	Quality[b] (%)	Value	Quality[b] (%)	
CSP (N.tex)	3781.3x	N/A	3752.3x	N/A	V, L, V*L
Elongation (%)	6.79x	<5	6.74x	<5	V, L, V*L
Tenacity (cN/tex)	14.48x	>95	14.20y	>95	V, T, V*L
Work to Break (cN.cm)	376.4x	49	369.3x	49	V, L, V*L
CV (%)	19.77x	83	19.88x	85	V, L, V*L
Thin Places (cnt/km)	189x	95	198x	>95	V, L, V*L
Thick Places (cnt/km)	931x	92	964x	94	V, L, V*L
Neps +200% (cnt/km)	741x	71	797y	77	V, L, T, V*L
Hairiness	4.66x	10	4.74y	14	V, L, T, V*L

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.
[b] Quality percentile is based on global yarn quality statistics for ring-spun carded yarn bobbins for weaving (USTER Technologies, 2007).
[c] V = variety; L = location; T = harvest treatment; V*L = variety-location interaction

Table 10. Selected results of 2007 carded-and-combed yarn analysis.[a]

	Picked		Stripped with FC		Significant Variables[c]
	Value	Quality[b] (%)	Value	Quality[b] (%)	
Noils (%)	16.50x	N/A	16.93x	N/A	V, L, V*L
CSP (N/tex)	4225.7x	N/A	4184.0x	N/A	V, V*L
Elongation (%)	7.10x	<5	7.04x	<5	V, L, V*L
Tenacity (cN/tex)	15.86x	90	15.83x	91	V, V*L
Work to Break (cN.cm)	427.2x	20	421.4x	22	V, V*L
CV (%)	14.98x	70	15.07x	72	V, L, V*L
Thin Places (cnt/km)	16x	84	17x	85	V, L
Thick Places (cnt/km)	108x	76	117y	77	V, L, T, V*L
Neps +200% (cnt/km)	59x	31	69y	39	V, L, T, V*L
Hairiness	4.22x	39	4.26x	41	V, L, V*L

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.
[b] Quality percentile is based on global yarn quality statistics for ring-spun combed yarn bobbins for weaving (USTER Technologies, 2007).
[c] V = variety; L = location; T = harvest treatment; V*L = variety-location interaction

As with the fiber quality parameters (tables 3-5), varietal and location impacts were substantial. Therefore, paired-sample t-tests ($\alpha = 0.05$) were conducted comparing differences in yarn properties between picked and stripped samples from the same plot to reduce varietal and location impacts. Results of the paired-samples t-tests for carded yarns revealed significant improvements in CSP, tenacity, nep count, and yarn hairiness from picked samples versus stripped samples (table 11). For carded-and-combed samples, picked cottons had fewer noils and resulted in improvements in yarn evenness and nep counts relative to stripped cottons (table 12). The percentage fibers combed out of the laps as noils was significantly correlated to SFC ($p < 0.0005$).

Table 11. Selected paired-sample t-test results of 2007 carded yarn analysis.

	Mean Difference[a]	p-value
CSP (N.tex)	27.3	0.030
Tenacity (cN/tex)	0.28	0.015
Neps + 200% (cnt/km)	-55	0.006
Hairiness	-0.08	0.003

[a] Mean difference = (Avg. of picked sample) – (Avg. of stripped samples).

Table 12. Selected paired-sample t-test results of 2007 carded-and-combed yarn analysis.

	Mean Difference[a]	p-value
Noils (%)	-0.425	0.002
CV (%)	-0.09	0.039
Thick Places (cnt/km)	-9.3	0.011
Neps + 200% (cnt/km)	-10.1	<0.0005

[a] Mean difference = (Avg. of picked sample) – (Avg. of stripped samples).

Compared to 2006, carded yarn tests in 2007 for both picked and stripped (field cleaned) samples showed increases in strength (as demonstrated by increases in CSP and tenacity; $p < 0.0005$ for all tests) but decreases in elongation ($p = 0.031$ for picked; $p = 0.025$ for stripped), which led to no significant differences in work to break ($p = 0.997$ for picked; $p = 0.677$ for stripped). Yarns in 2007 were also more even, as demonstrated by improvements in CV, thin places, thick places, and neps (+200%; $p < 0.0005$ for all tests). Hairiness improved for stripped samples between 2006 and 2007 ($p = 0.006$) but not for picked samples.

Combing was more appropriate for samples in 2007, when the average staple was 37, than 2006, when the average staple was 35. Like the carded yarn tests, both picked and stripped (field cleaned) samples showed increases in strength (as demonstrated by increases in CSP and tenacity; $p < 0.0005$ for all tests). While differences in elongation were not significant at the 95% confidence interval ($p = 0.067$ for picked; $p = 0.053$ for stripped), reductions in elongation were enough to offset gains in yarn strength such that no significant differences were detected in work to break ($p = 0.711$ for picked; $p = 0.658$ for stripped). Carded-and-combed yarns in 2007 were also more even, as demonstrated by improvements in CV, thin places, thick places, and neps (+200%; $p < 0.0005$ for all tests). No differences were detected between years in hairiness or noils for either harvest treatment.

Like 2006, compared to global averages, the yarn quality indices reported above for all harvest treatments indicate relatively poor yarn quality with a few exceptions: elongation for both carded and carded-and-combed yarns was excellent; work-to-break was average for carded yarns but good for carded-and-combed yarns; and hairiness, which was near average for carded-and-combed yarns but good for carded yarns.

Conclusions

The effect of harvest treatment on fiber quality was compared for four varieties of cotton commonly grown on the High Plains of Texas. Fiber quality indices were determined with HVI and AFIS instruments and were compared for cotton harvested with a spindle picker, a brush-roll stripper with a field cleaner, and the same stripper harvester without a field cleaner (in 2006 only). Each year, all samples underwent similar cleaning regimes during ginning.

In 2006, micronaire, length, and length uniformity as measured by HVI were better for picker harvested cotton than for stripped cotton leading to a higher loan value and average sale price for the producer. In 2007, when growing conditions were better and fibers were more mature, differences in fiber quality parameters between picked and stripped cottons were less pronounced leading to less discrepancy in the value of cotton harvested. However, in 2007, differences in nep counts, short fiber content, and visible foreign matter between harvest treatments were distinguishable.

The results of this study indicate that producers may realize greater fiber quality and lint value by using picker harvesters, but the magnitude of those differences may be a function of growing conditions and/or fiber maturity. Varietal differences also played a large role in determining fiber properties, but in 2007, no differences were seen in the value of harvested lint as a result of these differences. The results of this study indicate that, in years of adverse growing conditions, producers may realize greater fiber quality and lint value by using picker harvesters as indicated by USDA classing office data.

Few differences were detected in carded yarn quality between harvest treatments, while more pronounced differences favoring picked cotton were seen in carded-and-combed yarns. During both 2006 and 2007, the evenness of carded-and-combed yarns was improved by picking over stripping as measured by yarn CV, thick places, and neps (+200%), and the hairiness of carded yarns was reduced by picking. In 2007, when fibers were more mature, picking improved the CSP, tenacity, and nep counts of carded yarns. Noils, which were correlated to SFC, were also reduced by picking. In 2007, variety had a greater impact on yarn quality than harvest treatment.

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